

## WHAT IS CLAIMED IS:

1           1. A waveguide-type optical control device comprising:  
2           first and second directional couplers provided while  
3           leaving a predetermined spacing therebetween, said first and  
4           second directional couplers being constituted respectively by  
5           two right and left optical waveguides provided on a substrate;  
6           and  
7           a control unit provided between the first directional  
8           coupler and the second directional coupler, first, second, and  
9           third electrodes being provided respectively on the left side  
10          of the left optical waveguide, on the right side of the right  
11          optical waveguide, and between the two optical waveguides, said  
12          control unit functioning to control light, which passes through  
13          the two optical waveguides, according to a voltage applied to  
14          the first, second, and third electrodes,  
15          said first, second, and third electrodes being extended  
16          into the first and second directional couplers.

1           2. The waveguide-type optical control device according to  
2           claim 1, wherein the first and second electrodes are different  
3           from each other in shape.

1           3. The waveguide-type optical control device according to  
2           claim 1, wherein the first, second, and third electrodes are  
3           extended to a portion near the boundary between the first  
4           directional coupler and the control unit and the boundary  
5           between the second directional coupler and the control unit.

1           4. The waveguide-type optical control device according to  
2 claim 1, wherein the first, second, and third electrodes have  
3 been offset to the right or left side with respect to the  
4 center line between the two optical waveguides.

1           5. The waveguide-type optical control device according to  
2 claim 1, wherein the control unit is a phase shifter that  
3 controls the quantity of light, which passes through the two  
4 optical waveguides, according to the applied voltage.

1           6. A waveguide-type optical control device comprising:

2           a phase shifter provided with a first electrode section  
3 comprising an electrode provided on the left side of a left  
4 optical waveguide, an electrode provided on the right side of a  
5 right optical waveguide, and an electrode provided between the  
6 two optical waveguides; and

7           a directional coupler comprising two optical waveguides  
8 which are connected respectively to the two right and left  
9 optical waveguides in the phase shifter and are provided  
10 parallel to each other with the spacing between the two optical  
11 waveguides being partially reduced, said directional coupler  
12 being used in at least one of an optical branching section  
13 provided on the input side of the phase shifter and an optical  
14 coupling section provided on the output side of the phase  
15 shifter, the refractive index of the two optical waveguides  
16 being varied according to a voltage applied across the  
17 electrodes provided respectively on the left side of the left

18 optical waveguide and the right side of the right optical  
19 waveguide and the electrode provided between the two optical  
20 waveguides in the phase shifter,

21       said directional coupler being provided with a second  
22 electrode section comprising an electrode provided on the left  
23 side of the left optical waveguide, an electrode provided on  
24 the right side of the right optical waveguide, and an electrode  
25 provided between the two optical waveguides, the three  
26 electrodes constituting the second electrode section being  
27 electrically connected respectively to the three electrodes  
28 constituting the first electrode section provided adjacent to  
29 the second electrode section in the longitudinal direction of  
30 the two optical waveguides, the voltage applied to the first  
31 electrode section being applied to the second electrode section.

1       7. The waveguide-type optical control device according to  
2 claim 6, wherein the second electrode section has been formed  
3 by extending the electrodes constituting the first electrode  
4 section.

1       8. The waveguide-type optical control device according to  
2 claim 6, wherein the second electrode section has a  
3 construction such that the shape of the electrode provided on  
4 the left side of the left optical waveguide and the shape of  
5 the electrode provided on the right side of the right optical  
6 waveguide are asymmetrical.

1       9. The waveguide-type optical control device according to

2 claim 6, wherein the second electrode section is provided only  
3 at a portion near the boundary between the directional coupler  
4 and the phase shifter.

1 10. The waveguide-type optical control device according  
2 to claim 6, wherein the first electrode section and the second  
3 electrode section have been offset by a predetermined level  
4 with respect to the center line between the two optical  
5 waveguides.

1 11. The waveguide-type optical control device according  
2 to claim 6, wherein, in the second electrode section, the  
3 electrode provided on the left side of the left optical  
4 waveguide and the electrode provided on the right side of the  
5 right optical waveguide each comprise a plurality of electrode  
6 pieces which are arranged at a predetermined interval and have  
7 been connected to each other or one another through a fuse or a  
8 bonding wire.

1 12. The waveguide-type optical control device according  
2 to claim 6, wherein the electrode provided between the optical  
3 waveguides in the second electrode section partially or  
4 entirely overlaps with one of the two optical waveguides in the  
5 thicknesswise direction thereof.

1 13. The waveguide-type optical control device according  
2 to claim 6, wherein the second electrode section is disposed on  
3 the surface of a substrate on which the two optical waveguides

4 are provided through a buffer layer.

1 14. The waveguide-type optical control device according  
2 to claim 6, wherein each of the electrodes constituting the  
3 second electrode section is disposed so as to be substantially  
4 coplanar with the two optical waveguides.

1 15. The waveguide-type optical control device according  
2 to claim 14, wherein the electrodes constituting the second  
3 electrode section are provided within respective concaves  
4 provided on the surface of a substrate on which the two optical  
5 waveguides are provided.

1 16. The waveguide-type optical control device according  
2 to claim 6, wherein the second electrode section is disposed on  
3 the backside of a substrate on which the two optical waveguides  
4 are provided.

Sub A' > 1 17. The waveguide-type optical control device according  
2 to claim 6, 7, 8, 9, 10, 13, or 16, wherein the directional  
3 coupler is provided in each of the optical branching section  
4 and the optical coupling section and both the directional  
5 couplers are provided with the second electrode section.

1 18. A waveguide-type optical control device comprising:  
2 a phase shifter comprising two left and right optical  
3 waveguides, a first electrode provided on the left side of the  
4 left optical waveguide, a second electrode provided on the

5 right side of the right optical waveguide, and a third  
6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end  
8 of the phase shifter and functions to branch an optical signal  
9 introduced through one of the two optical waveguides into  
10 optical signal parts which are then introduced respectively  
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the  
13 other end of the phase shifter and functions to couple the  
14 optical signal parts received respectively from the two optical  
15 waveguides,

16 at least one of the first and second electrodes and the  
17 third electrode having been extended into a part or the whole  
18 of the first directional coupler or the second directional  
19 coupler.

1 19. A waveguide-type optical control device comprising:

2 a phase shifter comprising two left and right optical  
3 waveguides, a first electrode provided on the left side of the  
4 left optical waveguide, a second electrode provided on the  
5 right side of the right optical waveguide, and a third  
6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end  
8 of the phase shifter and functions to branch an optical signal  
9 introduced through one of the two optical waveguides into  
10 optical signal parts which are then introduced respectively  
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the

13 other end of the phase shifter and functions to couple the  
14 optical signal parts received respectively from the two optical  
15 waveguides,

16 at least one of the first and second electrodes and the  
17 third electrode having been extended into a part or the whole  
18 of the first directional coupler, at least one of the first and  
19 second electrodes and the third electrode having been extended  
20 into a part or the whole of the second directional coupler.

1 20. A waveguide-type optical control device comprising:

2 a phase shifter comprising two left and right optical  
3 waveguides, a first electrode provided on the left side of the  
4 left optical waveguide, a second electrode provided on the  
5 right side of the right optical waveguide, and a third  
6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end  
8 of the phase shifter and functions to branch an optical signal  
9 introduced through one of the two optical waveguides into  
10 optical signal parts which are then introduced respectively  
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the  
13 other end of the phase shifter and functions to couple the  
14 optical signal parts received respectively from the two optical  
15 waveguides,

16 said first directional coupler comprising, in its  
17 directional coupling section, first directional coupling  
18 section outer electrodes disposed respectively at a portion  
19 near the left side of the left optical waveguide and at a

20 portion near the right side of the right optical waveguide in  
21 the first directional coupling section and a first directional  
22 coupling section intermediate electrode disposed between the  
23 two optical waveguides in the first directional coupling  
24 section,

25 said first electrode and said second electrode having  
26 been electrically connected respectively to the first  
27 directional coupling section outer electrodes, said third  
28 electrode having been electrically connected to the first  
29 directional coupling section intermediate electrode.

1 21. The waveguide-type optical control device according  
2 to claim 20, wherein the first directional coupling section  
3 outer electrodes and the first directional coupling section  
4 intermediate electrode apply a voltage to a part of the optical  
5 waveguides constituting the directional coupling section to  
6 cause an electric field.

1 22. A waveguide-type optical control device comprising:

2 a phase shifter comprising two left and right optical  
3 waveguides, a first electrode provided on the left side of the  
4 left optical waveguide, a second electrode provided on the  
5 right side of the right optical waveguide, and a third  
6 electrode provided between the two optical waveguides;

7 a first directional coupler that is connected to one end  
8 of the phase shifter and functions to branch an optical signal  
9 introduced through one of the two optical waveguides into  
10 optical signal parts which are then introduced respectively



11 into the two optical waveguides; and

12 a second directional coupler that is connected to the  
13 other end of the phase shifter and functions to couple the  
14 optical signal parts received respectively from the two optical  
15 waveguides,

16 said second directional coupler comprising, in its  
17 directional coupling section, second directional coupling  
18 section outer electrodes disposed respectively at a portion  
19 near the left side of the left optical waveguide and at a  
20 portion near the right side of the right optical waveguide in  
21 the second directional coupling section and a second  
22 directional coupling section intermediate electrode disposed  
23 between the two optical waveguides in the second directional  
24 coupling section,

25 said first electrode and said second electrode having  
26 been electrically connected respectively to the second  
27 directional coupling section outer electrodes, said third  
28 electrode having been electrically connected to the second  
29 directional coupling section intermediate electrode.

1 23. The waveguide-type optical control device according  
2 to claim 22, wherein the second directional coupling section  
3 outer electrodes and the second directional coupling section  
4 intermediate electrode apply a voltage to a part of the optical  
5 waveguides constituting the directional coupling section to  
6 cause an electric field.

1 24. The waveguide-type optical control device according

Sub 22

2 to claim 20 or 21, wherein the first directional coupling  
3 section intermediate electrode has been offset with respect to  
4 the center line between the two optical waveguides constituting  
5 the first directional coupling section.

1 25. The waveguide-type optical control device according  
2 to claim 22 or 23, wherein the second directional coupling  
3 section intermediate electrode has been offset with respect to  
4 the center line between the two optical waveguides constituting  
5 the second directional coupling section.

1 26. A variable optical attenuator comprising:

2 a phase shifter provided with a first electrode section  
3 comprising an electrode provided on the left side of a left  
4 optical waveguide, an electrode provided on the right side of a  
5 right optical waveguide, and an electrode provided between the  
6 two optical waveguides; and

7 a directional coupler comprising two optical waveguides  
8 which are connected respectively to the two optical waveguides  
9 in the phase shifter and are provided parallel to each other  
10 with the spacing between the two optical waveguides being  
11 partially reduced, said directional coupler being used in at  
12 least one of an optical branching section provided on the input  
13 side of the phase shifter and an optical coupling section  
14 provided on the output side of the phase shifter, the  
15 refractive index of the two optical waveguides being varied  
16 according to a voltage applied across the electrodes provided  
17 respectively on the left side of the left optical waveguide and

18 the right side of the right optical waveguide and the electrode  
19 provided between the two optical waveguides in the phase  
20 shifter, whereby the attenuation level of the lights passed  
21 through the optical waveguides is controlled,

22 said directional coupler being provided with a second  
23 electrode section comprising an electrode provided on the left  
24 side of the left optical waveguide, an electrode provided on  
25 the right side of the right optical waveguide, and an electrode  
26 provided between the two optical waveguides, the three  
27 electrodes constituting the second electrode section being  
28 electrically connected respectively to the three electrodes  
29 constituting the first electrode section provided adjacent to  
30 the second electrode section in the longitudinal direction of  
31 the two optical waveguides, the voltage applied to the first  
32 electrode section being applied to the second electrode section.

1 27. An optical equalizer comprising:

2 an optical demultiplexer into which a wavelength  
3 multiplexed optical signal containing a plurality of optical  
4 signals with one or mutually different wavelengths is input and  
5 which demultiplexes the wavelength multiplexed optical signal  
6 into optical signals and outputs the demultiplexed optical  
7 signals;

8 the variable optical attenuator according to claim 26  
9 which selectively attenuates the demultiplexed optical signals  
10 by a predetermined attenuation level and outputs the attenuated  
11 optical signals; and

12 an optical multiplexer for multiplexing the attenuated

13 optical signals output from the variable optical attenuator.

1 28. The optical equalizer according to claim 27, which  
2 further comprises an attenuation level control circuit for  
3 controlling the variable optical attenuator so as to render the  
4 optical levels of the attenuated optical signals homogeneous.

1 29. The optical equalizer according to claim 27, which  
2 further comprises an attenuation level control circuit for  
3 controlling the variable optical attenuator in such a manner  
4 that a predetermined difference is provided between the optical  
5 levels of the attenuated optical signals.

1 30. An optical inserting/separating apparatus comprising:  
2 an optical demultiplexer into which a wavelength  
3 multiplexed optical signal containing a plurality of optical  
4 signals with one or mutually different wavelengths is input and  
5 which demultiplexes the wavelength multiplexed optical signal  
6 into optical signals and outputs the demultiplexed optical  
7 signals;

8 a wavelength varying filter for selectively separating an  
9 optical signals with predetermined wavelengths from the  
10 demultiplexed optical signals;

11 the variable optical attenuator according to claim 26  
12 which selectively attenuates the demultiplexed optical signals,  
13 which have passed through the wavelength varying filter, by a  
14 predetermined attenuation level and outputs the attenuated  
15 optical signals; and

16 a filter which selects and outputs the attenuated optical  
17 signals from the variable optical attenuator or externally  
18 inserted optical signals; and

19 an optical multiplexer for multiplexing the attenuated  
20 optical signals output from the filter or the inserted optical  
21 signals.

1 31. The optical inserting/separating apparatus according  
2 to claim 30, which further comprises an attenuation level  
3 control circuit for controlling the variable optical attenuator  
4 so as to render the optical levels of the attenuated optical  
5 signals and the inserted optical signals homogeneous.

1 32. The optical inserting/separating apparatus according  
2 to claim 30, which further comprises an attenuation level  
3 control circuit for controlling the variable optical attenuator  
4 so as to provide a predetermined difference between the optical  
5 levels of the attenuated optical signals and the inserted  
6 optical signals.

1 33. A waveguide-type optical control device comprising:  
2 a phase shifter comprising two left and right optical  
3 waveguides, a first electrode provided on the left side of the  
4 left optical waveguide, a second electrode provided on the  
5 right side of the right optical waveguide, and a third  
6 electrode provided between the two optical waveguides;  
7 a first directional coupler that is connected to one end  
8 of the phase shifter and functions to branch an optical signal

9 introduced through one of the two optical waveguides into  
10 optical signal parts which are then introduced respectively  
11 into the two optical waveguides; and

12 a second directional coupler that is connected to the  
13 other end of the phase shifter and functions to couple the  
14 optical signal parts received respectively from the two optical  
15 waveguides,

16 at least one of the first and second electrodes and the  
17 third electrode having been extended into a part or the whole  
18 of the first directional coupler or the second directional  
19 coupler, the third electrode in its extended electrode portion  
20 being provided so that a longitudinal electric field is applied  
21 to one of the two optical waveguides.

1 34. The waveguide-type optical control device according  
2 to claim 33, wherein the third electrode in its extended  
3 electrode portion is disposed on the top surface or the  
4 backside of one of the two optical waveguides so as to overlap  
5 therewith.

1 35. A process for producing a waveguide-type optical  
2 control device, comprising the steps of:

3 forming two right and left optical waveguides so as to  
4 construct a phase shifter and at least one directional coupler  
5 within a substrate;

6 forming a first electrode and a second electrode  
7 respectively on the left side of the left optical waveguide and  
8 on the right side of the right optical waveguide so as to

9 extend from the phase shifter to a part of the directional  
10 coupler, forming a third electrode between the two optical  
11 waveguides so as to extend from the phase shifter to a part of  
12 the directional coupler, and, in addition, forming a plurality  
13 of independent electrode pieces at a predetermined interval at  
14 the end of the second electrode and at the end of the third  
15 electrode, or forming a plurality of electrode pieces at a  
16 predetermined interval connected to each other or one another  
17 in a cascade form through a fuse; and

18 successively wire bonding the necessary number of the  
19 plurality of independent electrode pieces from the inner side,  
20 or successively fusion cutting the fuse of the necessary number  
21 of the plurality of cascaded electrode pieces from the outer  
22 side so as to bring the characteristic value of the directional  
23 coupler to a desired value.

100-1